Mapping *in situ* Optical Properties in Coastal Waters Using Slocum Coastal Gliders during RIMPAC 2006

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LONG-TERM GOALS

Characterizing *in situ* water turbidity is critical to numerous naval operations. In particular, water column turbidity impacts the efficacy of sensors that use optical measurements for a variety of purposes including laser detection of mines and prediction of the operational detection horizon for bioluminescence. To this end we have been developing an autonomous platform outfitted with this sensor package and reporting the data in near-real time prior to and during advance into a battle space. The endurance, water column coverage, stealth, and mobility of the Slocum Coastal Glider provides an ideal platform when coupled with the correct optical suite to accomplish this utility. Our long term goals is to develop and demonstrate the ability of Webb gliders to map the *in situ* optical proerties.

OBJECTIVES

During the MIREM 2004 and 2005 efforts we in collaboration with WetLabs and Metron have demonstrated that the Webb gliders are capable of carrying the optical sensors appropriate for mapping the incident optical conditions in mesotrophic coastal waters. Building on these accomplishments, our goal in 2006 is to demonstrate the capability of Webb gliders to characterize the optical properties in oligotrophic waters within the nearshore operational zone of the 2006 RIMPAC field effort. In June and July of 2006 an exercise was conducted with the AQS-24 Laser Line Scan (LLS) system during the RIMPAC operation offshore Hawaii. Our goal in support of this effort was to map the in-water optical properties to assess the potential, performance of the AQS-24 system. Specifically for the LLS, the performance issues to be focused on include the reacquisition and identification probabilities in a diverse range of coastal waters. The plan includes the potential of the LLS for the reacquisition and identification of various mine shapes (large & medium-size cylindrical and 2 'stealthy' shapes). These results will be communicated to operators whenever possible prior to RIMPAC field operations.

APPROACH

For this effort, we deployed a SLOCUM Webb glider to provide maps of the *in situ* optical properties that would feed system performance models. We planed was to fly through the specified areas of this exercise in order to collect a range of differing optical quality environments to evaluate expected variations in LLS performance. The glider was outfitted with the Scattering-Attenuation Meter (SAM)

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and backscatter ECO pucks providing inputs to EOID models. Data from the glider was transferred in real-time, via Iridium, and the optical data will be transferred to Metron and the physical data will be transferred to NAVOCEANO. Finally our goal was to allow NAVO and Naval personnel to redirect the glider based on conditions and fleet movements in the field.

WORK COMPLETED

The team participated in the June 2006 demonstration of vehicle operation during a two week deployment. Our efforts focused on scouting the experimental area prior to the LSS system

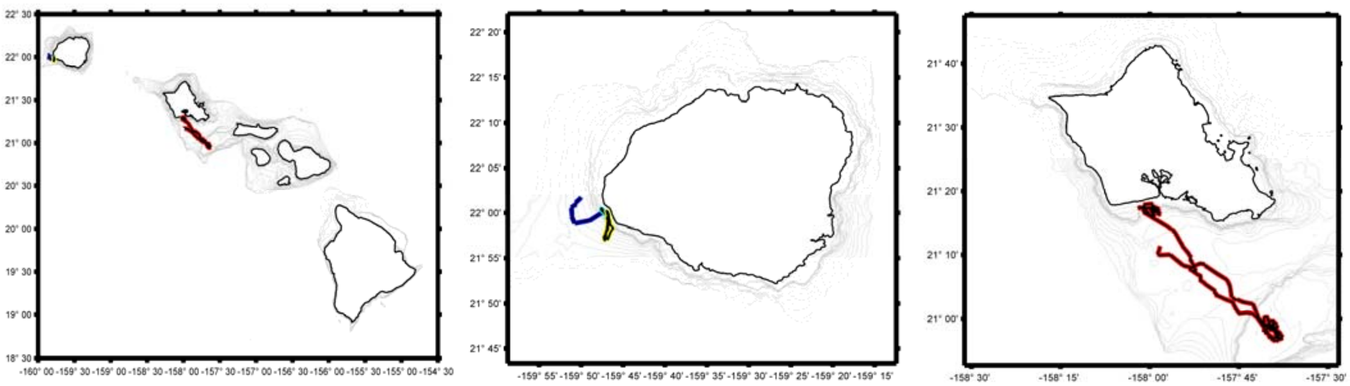

Figure 1. The glider deployments conducted as part of RIMPAC 2006.

deployment was successful with data being delivered to system performance models prior to LSS planning missions. The systems were successfully flown in all three RIMPAC field sites. The only major issues involved ecotourism groups which on two occasions recovered the glider assuming that it was crippled. During RIMPAC, in the three sites, the glider was deployed four times collecting 3006 vertical profiles flying 284 kilometers. During the mission spanning the Puuloa Underwater Range after the mission brief the Commodore of the RIMPAC exercise redirected the glider to the Penguin Banks remotely. In the first field site at the Pacific Missile Range Facility the glider collected 874 profiles and flew 63 kilometers. During the mission at the Puuloa Underwater Range and Penguin Banks the glider collected 2132 profiles as it flew 221 kilometers.

RESULTS

The glider collected spectral backscatter, temperature, salinity, fluorescence and depth-averaged currents data. Datasets for the attenuation were also collected using the SAM sensor. This data set was invaluable for improving the SAM, given it was the clearest waters in which the sensor had been flown. At the Pacific Missile Range, the offshore waters were oligotrophic and optical signals were close to the instrument limits. This provides a unique data set which allowed the SAM sensor to be calibrated. Results from the flight at the Pacific missle range are shown in Figure 2. In the shallow waters optical signals were higher by a factor of 2 to 3 (Figure 2). The attenuation values, after correction for the clear water conditions offshore, resembled the backscatter; however it is was clearly near the instrumental limits given the noise in the signals. The other major challenge flying the glider in these waters was the strong currents. Data was transmitted and thid allowed forecasts for LSS systems.

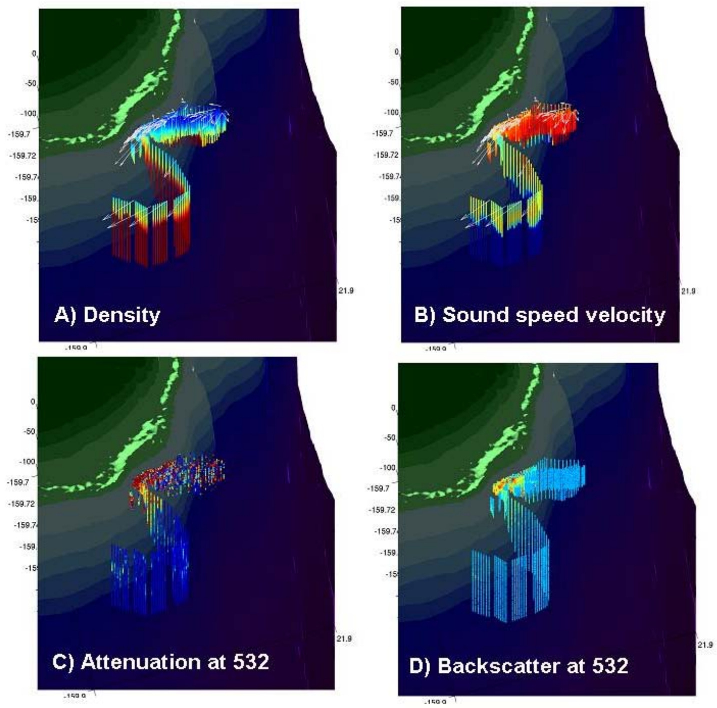

Fig. 2. Glider data collected at the Pacific Missile Range during the 2006 RIMPAC effort. A) The variability in density (22.7 blue and 23.3 red). The white lines are the depth averaged currents. B) The variability in the sound speed velocity (1535 blue -1538 red). C) The variability in the attenuation collected at 532 nm (0 blue to 1 red). The high values in the upper water on the shelf are not real. C) The variability in backscatter at 532 nm (0 blue to 0.001 red).

The second deployment at the Puuloa Underwater Range and Penguin Banks was conducted over the two weeks. The mission was sufficiently long that the both optical sensors began to become biofouled. This biofouling impacted the Penguin Banks and Puuloa Underwater Range stransect leg (Figure 3, the transect with high backsctatter values). The values in the shallow waters at both sites were turbid (Figure 3). Despite the higher turbid values nearshore, the waters were sufficiently clear that the system performance models predicted that the LSS system would have be able to image objects in the bottom waters. The waters inbetween the waters the two shallow waters site were extremely clear. The RIMPAC command decided when the glider was sent into and out of both field sites.

The data during the Puuloa Underwater Range and Penguin Banks deployment was low. This noise was very episodic both in the shallow and deep waters. During the deployment we assumed that it reflected the sensitivity limits of the sesnors in these clear waters. Upon recovery, the Rutgers diver noticed signficant fish schooling under the Glider (Figure 4). We currently believe much of the episodic noise reflected the schooling fish that would lead to enhanced backscatter for both the backscatter and

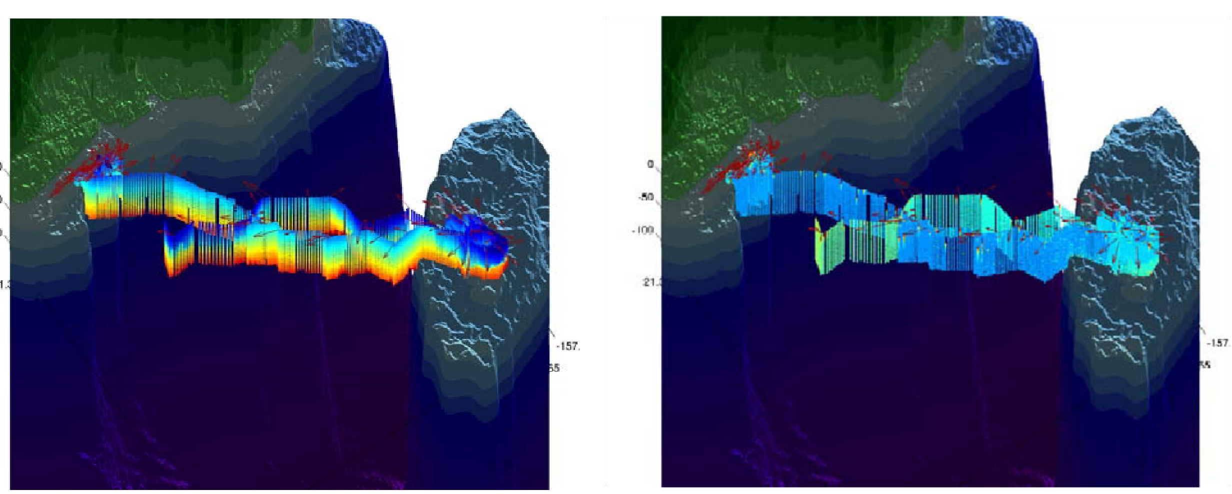

Fig. 4. The transect of the glider showing the temperature and backscatter data. The figure on the left is temperature; Figure on the right is backscatter as 532 nm.

attenuation data. We are currently working with Dr, Thomas Frazer who is a behaviour ecologist at the University of Florida at Gainseville to see if the noise in the optical data can be ascribed to the schooling fish. The glider at the end of the tranect the glider began to act erractically. Examination of the glider upon reocvery determined that the glider had been struck violently from below with suffcient force to bend the CTD (this is the first time that this has been observed in 25,000 kilometers flying

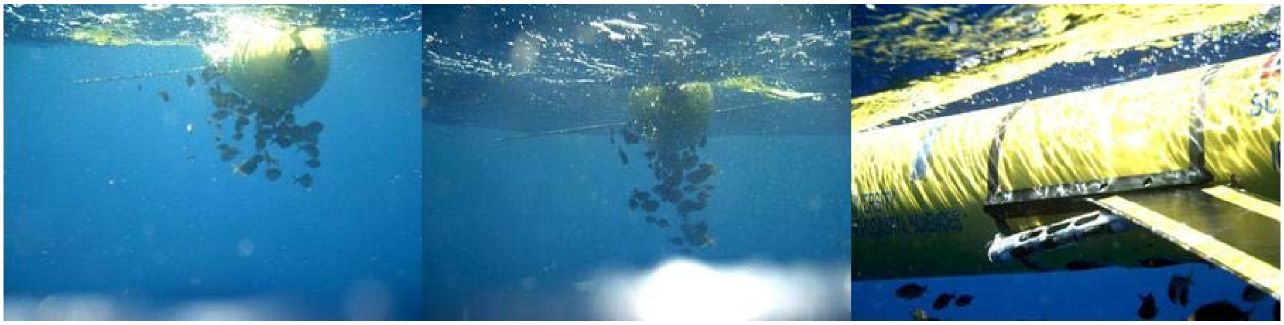

Fig. 5. The fish schooling under the Webb glider at the end of the RIMPAC deployment. The fish are observed to be schooling directly under the glider by the optical sensors. The CTD upon close inspection is bent by almost 30 degrees suggesting blunt upward trauma from below.

gliders underwater by our group) (Figure 5). We believe that glider was struck by a shark.

IMPACT/APPLICATIONS

Characterizing *in situ* water turbidity is critical to numerous naval operations. In particular when water column turbidity impacts the efficacy of sensors that use optical measurements for a variety of purposes. These optical measurements are used to improve laser detection of mines and prediction of the operational detection horizon for navy divers. The ability to deploy and covert insertion of assetts "over the horizon" will provide a critical assett for planning mine counter measures. The turbidity data has been demonstrated in recent MIREM and RIMPAC field efforts. In these efforts the utility of the data for mission planningsin the denied areas was demonstrated. The addition of optical properties to the gliders have expanded the utility of gliders for mine counter measures in addition to the anitsubmairne applications demonstrated during the Sharem field efforts.

TRANSITIONS

The success of the gliders in a variety of the field exercises have resulted in the active procurement of the gliders for the fleet. The assets will likely become assets of both the NAVOCEANO and the fleet. Recent plans call for 300 gliders to be purchased. One of the major advantages of the Webb Glider is that it provides a modular platform. The development of an optical science bay that can support mine counter measures will thus be of great utility to evolving fleet of Naval gliders. In addition to the actual platforms, the existing Glider processing software developed by Rutgers and WRC are being transitioned to NAVOCEANO. The software includes the processing and formatting of the data to facilitate the data assimilation into operational naval models.

RELATED PROJECTS

This project leverages and complements several ONR efforts. These gliders will play a major role in the ONR sponsored OASIS field program in fall 2007. That effort will assess the role in storms in regulating the sediment resuspension and transport processes in the coastal ocean. The AOP gliders will provide the spatial context of the time series collected by the Eulerian assets to be deployed at the Martha Vineyard's Cabled Observatory. Developing the optical capability for gliders will directly benefit a recently funded Major University Research Initiative (MURI) which will develop a data assimilative physical-optical modeling-observation system consisting of an ensemble of optical models of varying complexity in order 1) to improve our predictive skill for forecasting ocean color and 2) improve physical models by using ocean color to discriminate hydrographic features not detected using traditional data streams. This MURI will study the regulation of ocean color for a broad western boundary continental shelf with a specific focus on regions of high optical variability (fronts), which coincides with regions of high acoustic uncertainty. The development of the optical gliders will directly benefit this effort.

PUBLICATIONS

One publication has been submitted and is currently under review. The manuscript was submitted to the Journal of Underwater Robotics.

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